A rhetorical reconsideration of knowledge management: Discursive dynamics of nanotechnology risks

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Abstract:

For some time, it has been argued, the United States and other "developed" nations have been caught up in a shift from an industrial to a post-industrial or knowledge society (e.g., Bell, 1973; Drucker, 1994). In this new society, experts use their commodified knowledge to rationally order resources in the resolution of problems. However, this "dream" has endured considerable criticism, and for several reasons. For example, though innovation in information and communication technologies has been considerable, the resulting products carry social consequences and may actually create problems and destabilize culture (Blackler, Reed, & Whitaker, 1993). As well, capitalism seems less rational today, tending toward flexibility and disorganization (Offe, 1985). Thus, though it may be accurate to say that we have more knowledge today, it does not necessarily follow that this growth remedies social problems.

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Chapter 1

A Rhetorical Reconsideration of Knowledge Management: Discursive Dynamics of Nanotechnology Risks

Roy Schwartzman and David Carlone

Introduction

For some time, it has been argued, the United States and other "developed" nations have been caught up in a shift from an industrial to a post-industrial or knowledge society (e.g., Bell, 1973; Drucker, 1994). In this new society, experts use their commodified knowledge to rationally order resources in the resolution of problems. However, this "dream" has endured considerable criticism, and for several reasons. For example, though innovation in information and communication technologies has been considerable, the resulting products carry social consequences and may actually create problems and destabilize culture (Blackler, Reed, & Whitaker, 1993). As well, capitalism seems less rational today, tending toward flexibility and disorganization (Offe, 1985). Thus, though it may be accurate to say that we have more knowledge today, it does not necessarily follow that this growth remedies social problems.

Perhaps more fundamentally, and a point we take up in this chapter, the dream of a post-industrial society has been criticized for its understanding of knowledge. Rather than considering knowledge as objective and certain, as "Truth," we conceptualize knowledge as socially constituted, ambiguous, and political. We argue that knowledge management may be usefully seen as a process by which knowledge is contested in public forums. In this chapter, we approach knowledge management, not as an issue of dissemination within an organization, but more as an issue of representation to various personae. The heart of knowledge management lies in what counts as knowledge, and what counts as knowledge depends on how people claim to know.

The discursive aspect of knowledge management rarely receives consideration in scholarly discussions. The question of what counts — and what gets promoted — as knowledge is as much a question of communication as of epistemology or organizational theory. Kofman and Senge (1995) caution against reifying the terminology of knowledge management and learning organizations, observing that these linguistic creations do not so much "describe a preexisting reality" as provide enabling or constraining models for behavior (p. 32). Extending their point, what counts as knowledge depends on how knowledge claims are constructed rhetorically. This chapter embarks on how knowledge about nanotechnology (practical applications of particle alterations on the atomic level) is constructed through its public portrayals. A long tradition of research has established the centrality of metaphors in the propagation of scientific knowledge (Rothbart, 1997) and in the formation of knowledge itself. In this case, metaphors, images, and stories are the sites of contesting interests, all having a stake in whether nanotechnology innovations acquire a beneficent or belligerent character.

Several research questions guide this inquiry:

1. How do the criteria for what counts as knowledge change when knowledge disseminates beyond the original community of knowers? Specifically, what role does language play in transforming technical scientific findings into depictions of benefits and risks that non-scientists can evaluate?
2. How do the criteria for evaluating risk change from one knowledge community to another? Can (and should) there be a universal grammar of risk? If so, whose knowledge should guide risk assessment?
3. How should the scientific community and other stakeholders deal with stimuli and threats to knowledge? The case of nanotechnology raises questions about the interfaces between knowledge and power, especially whether the producers of knowledge should control assessments of risks and rewards attendant to the knowledge.

Approaching these questions highlights the role of communication and politics in knowledge management. Knowledge management involves making a persuasive case for what counts as knowledge. Knowledge management, therefore, becomes an issue of communication style as well as (and perhaps more than) the accuracy, control, and flow of information.

Communication analysis provides an especially apt approach because the quantum mechanics that guide molecular-level operations proves far too technical and counter-intuitive for public discussion. For nanotechnology to be "sold" as viable and safe (or as virulent and scary), it must be connected to more familiar terms and placed within a coherent story that makes a believable case for support or suspicion. Informed public discussion of nanotechnology operates through metaphors and images that make it understandable. The window of opportunity for examining public representations of nanotechnology is open now. Since "in terms of public discourse, nanotechnologies have yet to gain any major place in public or popular media representations" in the US or the UK (Rogers-Hayden & Pidgeon, 2007, p. 346), the stakeholders in nanotechnology development still can shape the prevailing portrayals of the field. Public opinion polls find that overall judgments about nanotechnology are neutral or that people remain uninformed because extensive media coverage and public discussions have yet to occur (Williams & Adams, 2007). Whether nanotechnology gets framed as the next polio vaccine or as the next Frankenstein relies on which sets of images resonate with policy-makers and researchers.

This chapter first focuses on the relationship between knowledge management and power, making the case that the practice of knowledge management can restrict or expand access to knowledge. Knowledge management therefore closely connects with ways that systems of power are established and maintained, especially in relationships between scientists and non-scientific communities. Next, the chapter discusses the role language plays in management of knowledge about nanotechnology. Close examination of an optimistic characterization and a pessimistic theme illustrate how the course of knowledge can follow the patterns established by discourse. Finally, consideration turns to the larger issue of how to conceive of the ways that nanotechnology knowledge percolates through society. A top-down model of scientists enlightening the ignorant masses presents many difficulties. A dialogically informed relationship of checks and balances among multiple constituencies provides a more thorough, less patronizing, and ultimately more productive approach to nanotechnology.

Knowledge Management as a Social Issue

We next briefly sketch the understanding of knowledge as socially constructed. In more detail, we then consider an implication of this position, namely that knowledge is ambiguous and, thus, must be managed.

Knowledge as a Social Construct

Writing several decades ago, Berger and Luckmann (1966) persuasively argued that what humans take to be natural about themselves and the world around them actually derives from their socialization into a group. As groups vary, so, too, does the nature and content of the socialization into those groups and, subsequently, what members of a group take to be natural about their world. Another classic work from the same period struck a similar chord. Kuhn (1970) demonstrated that scientific knowledge and practice may only be seen as "objective" or "cumulative" from the perspective of the paradigm guiding the science. This (now) basic idea that objective knowledge about the world in fact stems from particular groups of people in particular times and places has been taken up by countless other scholars across the disciplines, including psychology (e.g., Gergen, 1994), communication, (e.g., Shotter, 1993), and business management (e.g., Weick, 1979). Repeatedly, this body of scholarship shows knowledge to be created, maintained, and transformed through social interactions and practices. More recently, a social constructionist perspective has informed some of the scholarship on knowledge management.

First, according to Tsoukas and Vladimirou (2001), "knowledge is the individual ability to draw distinctions from within a collective domain of action, based on an appreciation of context or theory, or both" (p. 979). Two aspects of this definition deserve comment. First, the ability to draw distinctions rests in part on the degree to which the individual and her/his community have developed a language to talk about and understand an object, event, domain, and so on. Following Foucault (1972), we would add that this language, or discourse, actually helps create perceptions of objects and events under consideration. Further, the discourse helps establish the parameters for what may be known and how, for what falls within the bounds of "truth." Second, the need to appreciate context suggests that knowledge changes as it encounters different contexts of creation and application. Note the political implications of communication and context embedded within the definition of knowledge offered by Tsoukas and Vladimirou. Limiting communication about and contexts for knowledge excludes other unsanctioned voices. Though knowledge always involves meaning and judgment (Alvesson, Kärreman, & Swan, 2002), many are often unable to participate in the processes of meaning and judging.

Second, Alvesson and Kärreman (2001) point out that theorists and practitioners of knowledge management often see knowledge as both socially constructed and objective, moving back and forth between the positions. For our purposes, we are less interested in consistency. Rather, what interests us is how the two positions may be used strategically, depending on the particular circumstances and needs of an individual or group. For example, those creating knowledge may build upon social constructionist versions of knowledge. But, when they take their ideas public, they may be inclined to frame their work as scientific and objective, as this forecloses some scrutiny, oversight, and controversy. In this way, the knowledge becomes ideological, caught up in a regime of truth regulating who may participate and how (Foucault, 1980).

Finally, organizational knowledge may be only partially separated from its conditions of creation and transformed into a commodity. Rather, organizational knowledge always remains somewhat personal and contextual (Polanyi, 1975; Tsoukas & Vladimirou, 2001). Knowledge is personal in that the individual remains unaware of all that she/he knows and does. Over time, knowledge becomes part of a person's common sense, operating below the level of awareness and becoming difficult to articulate to others. Including others in the processes of knowledge creation and application may likely surface some of this personal knowledge.

These comments begin to point toward how we conceptualize knowledge management: not simply as a management practice oriented to capturing and translating knowledge into products, but as a communicative practice whereby knowledge is continually and strategically crafted by and for certain audiences. We develop this idea in the next section.

The Power Attendant to Managing Knowledge

On their own, "knowledge" and "management" often establish hierarchical relations (Alvesson & Kärreman, 2001). Knowledge suggests a distinction between those with knowledge and those without. Management references the distinction between those who plan the work for those who do the work. When the two terms are articulated (Hall, 1985), "knowledge management" amplifies this effect, emphasizing an elite and new kind of expertise. Articulating "knowledge" and "management" and invoking the phrase silences various constituencies. Perhaps it is not surprising, then, that despite notes of caution, the strong tendency within knowledge management has been to emphasize themes of rationality, order, control, and predictability (Swan & Scarbrough, 2001), providing the first steps in managing knowledge. These values and their practice create and maintain distinctions, stratifying groups (Greene & Hicks, 2005). As Deetz (1992, 1995) has shown, these are precisely the characteristics that mark managerialism, narrowing the scope of organizational decision making. Knowledge management, then, is a political stance that often limits other voices and, in the process, actually inhibits knowledge and learning.

In his work on knowledge-intensive firms, organizations, and workers, Alvesson emphasizes the inherently ambiguous nature of knowledge and knowledge-intensive work and the various responses to this ambiguity. Alvesson (1993) argues that considerable ambiguity surrounds: 1) what counts as knowledge, 2) how people create knowledge, and 3) what results from knowledge. Importantly, these sources of ambiguity cannot be removed. In fact, the presence of ambiguity opens space for expert intervention.

Since ambiguity cannot be eradicated, it must be managed. "The ambiguity of knowledge and the work of knowledge-intensive companies means that 'knowledge', expertise' and 'solving problems' to a large degree become matters of beliefs, impressions and negotiations of meaning" (Alvesson, 2001, p. 870). Fortunately for knowledge firms and workers, "knowledge" holds such positive connotations in the contemporary environment that simply invoking the term may sway people to see things in a particular way. For instance, because of this currency many people are pre-disposed to believe that the interventions of an expert will work. Indeed, this belief is fundamental for when absent, an intervention is sure to fail (Alvesson, 1993). In other words, faced with uncertainty, people find guidance in myths about the ability of experts and their interventions (Carlone, 2006). Myths, such as the belief in experts, act as a surrogate for rationality guided by logical calculations. Alvesson extends this insight to the world of business to argue that "knowledge management" is, in fact, a surrogate for rationality.

The appearance of knowledge, then, may in and of itself prompt others to see a person, group, or firm as knowledgeable. Thus, people and firms make significant investments in cultivating the appearance of knowledge. In short, to be recognized as an expert, one must persuade others that she/he is an expert. For this reason, working in the area of knowledge management means working with rhetoric. A knowledge-intensive firm or group may be thought of as a system of rhetoric (Alvesson, 1993).

Many management strategies exist. For instance, firms and workers may connect themselves and their work to "cutting edge" initiatives and emphasize key aspects of identity, such as a quirky organization culture or playful workplace architecture (Alvesson, 1993), or a personal image as a "cultural creative" (Florida, 2002). In these strategies, unique traits equate with "new/cutting edge" which, in turn, equates with "knowledge." For example, *Nanotechnology for Dummies* rationalizes the decision to buy the book by noting that "nano is so cutting-edge that new questions about it are coming up every day" (Booker & Boysen, 2005, p. 1).

More relationally, knowledge and its image rely upon creating relationships with internal and external parties so that these parties see actors as knowledgeable. Linking to other experts cultivates an image of expertise. The ritual of scholarly citations in references and footnotes testifies to a researcher's membership in a community of experts (Crane, 1972). However, it may also be that *not* linking to certain groups, those who lack knowledge, also is a part of image management. The intensity of managing ambiguity also often leads firms to associate with other already known firms for "dealing with unknown companies would only aggravate their feelings of uncertainty and anxiety" (Alvesson, 2001, p. 874). A closed system begins to develop, limiting outside relations and influences and potentially limiting learning and innovation (Albrecht & Hall, 1991).

Another strategy for creating and maintaining the perception of knowledge requires "obscuring uncertainty and counteracting reflection" (Alvesson, 1993, p. 1011). Paradoxically, making knowledge claims often works to hide and diminish uncertainty, doubt, and reflection (Alvesson, 2001). Intriguingly, Alvesson & Kärreman (2001) argue that as knowledge increases, the space for management (control by managers) decreases. And, as management increases, the space for knowledge decreases. Applied to the relations among scientists and other constituencies, however, we find that internally, among insiders, knowledge is featured. Externally, management is featured. In other words, when it comes to interacting with various non-scientific groups, nanotechnologists emphasize themselves as experts with objective knowledge. This places others as non-experts engaging in subjective activities. The concept of knowledge management affords space for this strategy in placing people as insiders and outsiders. It is the non-expert "others," the outsiders, who must be managed.

Many of these dynamics play out internally as well. In his analyses of a dot-com startup, Lyon (2004) found that cultural knowledge may function as a form of cultural capital. Those more attuned to an organizational culture are able to distinguish themselves from those who know less about the culture. However, organizational success lies in having widely shared cultural knowledge to minimize cultural capital, or discrepancies in knowledge. In another work (Lyon, 2005), he shows that expert knowledge only functions as intellectual capital if the context allows for such translation. In the case presented below, while nanotechnologists hold the intellectual capital in the contexts of basic research, when they translate that research into innovations for other groups, those other groups may vie for and have intellectual capital. Moreover, we argue that other stakeholders should have intellectual capital in such conditions. Thus, freezing, or automatically transferring, intellectual capital from one context to another should be avoided. Instead, we argue that intellectual capital does not simply become diluted, but can multiply as the dimensions of discourse expand to include more participants. End users of innovation are active in constructing the meaning and nature of nanotechnology, much as the audience for creative labor plays a role in constructing the meaning and value of the performance (Adkins, 2005). At the same time, the power of labels such as "scientist" and "knowledge" may inhibit the engagement of end users with scientists. Critique and "unlearning" (Lyon, 2005, p. 268) are necessary to help engagement. Indeed, a more direct, productive engagement between scientists and other communities of knowledge-seekers will rely on more than platitudes about democratic decision making. "The use of democratic language can serve to obscure the power relations of science and the different opportunities for involvement in the decisions which affect research and funding priorities and the eventual applications of science in technologies" (Peterson, Anderson, Wilkinson, & Allan, 2007, p. 118). We now turn to the manipulations of language that shape what counts as knowledge about nanotechnology.

Nanoknowledge and Risk Perception

When is carbon not really carbon? More generally, when does any substance act in ways totally different from its ordinary chemical properties? Answer: When it gets very, very small. In 1959, Richard Feynman — widely regarded as the father of nanotechnology — made an apparently reckless prediction:

> Atoms on a small scale behave like *nothing* on a large scale, for they satisfy the laws of quantum mechanics. So, as we go down and fiddle with the atoms down there, we are working with different laws, and we can expect to do different things. We can manufacture in different ways. (Feynman, 1999, p. 136)

His reckless prediction has become serious reality. Nanotechnology (derived from the prefix *nano*-, meaning one-billionth) encompasses the practical applications of manipulating matter on the atomic and molecular scale of one-billionth of a meter—80,000 times smaller than the width of a human hair. Structural manipulations of matter at this level radically change how a substance behaves, and the commercial potential seems almost unlimited. Single-walled carbon nanotubes, single-atom thick hollow cylinders of carbon, are more than 50 times stronger than steel and are efficient conductors that could miniaturize electronics thousands of times smaller than current technology. Target and other stores already sell Dockers stain-repellant "nano pants" coated with microfibers that protect the pants from intrusive particles that might soil them. Restructured molecules also can deliver medicine directly to certain areas of the body and target release to coincide in the presence of certain types of cells, making nanotechnology an attractive way to administer drugs efficiently. At the nanoscale, various substances acquire special visual properties such as luminescence when they encounter certain types of cells, making them useful to identify sites of infection or toxicity. Some sunscreens on the market use titanium dioxide nanoparticles as transparent shields against sunlight. The total value of nanotechnology products on the market is expected to top $2.5 trillion by 2014 (Maynard, 2007).

With the economic stakes so large, surprisingly little attention has been devoted to how the concepts and implications of nanotechnology get framed in public discussions. Nanotechnology risks, like other risks associated with technologies, are matters of perception. Since perceptions are shaped by communication, the degree of risk associated with nanotechnology relies on knowledge claims, i.e., the presentation of images, narratives, and figurative language that constitute what counts as knowledge. Nanotechnology offers especially fruitful territory for connection with knowledge management. A recent issue of *Health, Risk and Society* devoted to nanotechnology noted that "understanding and perceptions of health risks are shaped by communication processes" (Petersen et al., 2007, p. 118), which emphasizes the centrality of communication to the construction of knowledge.

Nanotechnology highlights the construction of knowledge claims because the field is so new and esoteric. Innovations in nanotechnology are presented dramatically and as quantum leaps forward. Audiences not schooled in the scientific technicalities receive a barrage of claims that resemble modern alchemy (Munn Sanchez, 2004). Ordinary substances, such as carbon, transform by nanotechnology into substances with dramatically different or enhanced properties. Minimally conductive substances become superconductors; fragile substances form bonds that make their tensile strength outperform dense metals; porous materials become impervious to foreign matter. With the methodological routes to these transformations mysterious to non-specialists, researchers must rely on non-technical means of persuasion, such as building a socially recognized aura of expertise that would legitimize claims as knowledge instead of speculation (Munn Sanchez, 2004). Indeed, "the social and political accounts of science can be as important as the material (technical) descriptions" (Faber, 2006, p. 142).

Nanotechnology debuted as a serious topic of public discussion in 1986, with the publication of K. Eric Drexler's *Engines of Creation* (Berube, 2006; Faber, 2006). The book explained in highly readable prose the sweeping innovations that nanotechnology would bring — potential benefits and risks. Drexler qualifies both as a nanotechnology pioneer and somewhat of a pariah, an ambivalent identity often worn by knowledge innovators. Listed in *Nanotechnology for Dummies* as one of the "nanotech movers and shakers" and classified with Feynman as one of the nanotech "visionaries," Drexler receives an ambivalent acknowledgment. Drexler "lays the groundwork for the public's current perception of nanotechnology (some of which is still, um, mired in speculation) in his 1986 book *Engines of Creation*…" (Booker & Boysen, 2005,

p. 324). The book did, however, generate "a wider interest in nanotechnology and brought it to the attention of the public" (Booker & Boysen, 2005, p. 324).

Content analysis of articles about nanotechnology in the popular press from 1986 (the year Drexler's landmark *Engines of Creation* was published) through 1999 reveals little convergence in the terminology that described nanotechnology (Faber, 2006). This failure to coalesce indicates that nanotechnology has not yet established a firm linguistic identity in public discussion. What counts as knowledge in nanotechnology remains highly contestable. Knowledge management in this area relies on rhetorical maneuvers to establish what counts as knowledge to audiences that may affect continuation of research, decide on providing resources that enable research, or deal with the effects of the research. After discussing the massive value of nanotechnology products, the chief nanotechnology advisor for the Woodrow Wilson International Center for Scholars admits that very little is known about the extent, nature, and severity of health risks that might accrue from nanomaterials (Maynard, 2007). Rhetoric comes into play when issues cannot be settled with certainty. Rhetoric operates within the realm of probability, seeking adherence to positions on the basis of available evidence instead of dealing with logical necessities. Since judgments of nanotechnology risks must involve "decision-making based on incomplete information" (Maynard, 2007, p. 10), they must rely on rationales other than proofs that compel assent. Absent conclusive proof, scientists must play by the rules governing public discourse — the realm of rhetoric.

To illustrate the rhetorical stakes in nanotechnology's development, we focus on two diverse terms and their usages, one associated with health risks and the other reflecting optimism about nanotechnology. Not surprisingly, they entered public parlance after Drexler's *Engines of Creation* helped popularize them. Depending on how future developments in nanotechnology proceed, either of these terms and their implications could generate the defining images of the field. The discussion begins with the optimistic rhetorical construction of nanotechnology's potential.

Playing With Buckyballs

A breakthrough occasion for nanotechnology was the 1985 discovery of a special structure of carbon atoms, an achievement that won the

1996 Nobel Prize in chemistry. These collections of 60 carbon atoms form a pattern of hexagons and pentagons that resemble the patches on a soccer ball's surface. C_{60} also bears a strong resemblance to the geodesic domes designed by R. Buckminster Fuller, hence the official name of these particles: buckminsterfullerenes. The public discussions of these substances shed light on the discursive framing of nanotechnology's promise. The very name of these particles reflects a playful personification that forestalls concerns about their potential hazards. Aside from acquiring their name from the developer of the geodesic domes that the particles resemble, fullerenes are commonly known as "buckyballs." This nicknaming has spread to related particles. "Buckybabies" have the same atomic structure with fewer than 60 carbon atoms. "Fuzzyballs" are buckyballs attached to 60 hydrogen atoms.

Buckyballs have remarkable properties, such as tensile strength much greater than steel, restoring their original shape after being crushed, and — especially when rolled into carbon nanotubes — having superconductivity. At the same time, early suspicions about buckyball risks have arisen. For example, a widely publicized study in March 2004 showed that fish developed brain damage within 48 hours when they swam in buckyball-infused water. Scientists at Rice University quickly announced research that showed ways to coat buckyballs to reduce their toxicity, but the door to buckyball risks had been opened. Apparently the management of risk perception succeeded, since the *New Scientist* article that summarized these events bore the title "Buckyballs made safer for humans" (Davis, 2004). This reassuring title stands in stark contrast to the reports summarizing the fish toxicity study. The watchdog Action Group on Erosion, Technology and Concentration, known as the ETC Group, had titled its April 2004 summary "Nano's Troubled Waters" (Action Group on Erosion, Technology and Concentration, 2004). Rhetorical management of risk perception was well underway long before this attempt to burst the buckyball.

The Australian Academy of Science published an orientation to buckyballs that framed nanotechnology in playful, harmless terms. The explanation of buckyballs begins by treating them as sports paraphernalia, specifically soccer balls: "When buckyballs bounced onto the scene in 1985, they became an overnight sensation. More than a decade later, scientists are still trying to score goals with these extraordinary molecules" (Australian Academy of Science, 1999). The piece concludes by returning to the soccer analogy. While the public waits for large-scale use of buckyballs, "hundreds or even thousands of chemists, physicists and molecular biologists in laboratories around the world continue to play molecular football with these most intriguing of structures" (Australian Academy of Science, 1999).

This kind of portrayal could pre-empt suspicions about nanotechnology. After all, what sort of threat might playful balls pose? Lighthearted treatments, however, also carry risks. If some preliminary studies about buckyball hazards are confirmed, then scientists could be accused of misrepresentation by publicly lowering perceptions of risk through utilizing language that discounts harms.

Vivid worst case scenarios, while not representative examples of a technology's development, easily become the defining images of that technology. For example, the meltdowns at Three Mile Island and Chernobyl permanently tainted the nuclear power industry. So far, no high-profile disaster has occurred with nanotechnology, so the specter of nanobots run amuck or other wayward developments does not (yet) haunt the field (Berube, 2006). Still, a major mishap could contaminate public perceptions of nanotechnology even amidst reassurances that the proprietors of knowledge (the researchers) supposedly have everything under control. This point has not escaped the perfume and cosmetics industry, which already employs nanotechnology widely in skin care products and suntan lotions. The Cosmetic Toiletry and Perfumery Association nervously notes: "Nanotechnology has the potential to become a major public relations disaster in the same way as genetic modification, in spite of scientific evidence regarding safety and the potential benefits of this technology" ("Of risks and benefits," 2007, p. 42). The potential crisis seems to involve the potential for genuine knowledge to become subsumed by hypothetical horror stories. Such framing, however, reflects a fundamental misconception of knowledge management.

The threat to maintaining accurate knowledge lies not simply in the struggle between knowledge and misinformation, but between different criteria for qualifying a claim as knowledge. This proposition has substantial impact for knowledge management. Instead of defending technical knowledge against the darkness of ignorance, those who promote informed discussion of nanotechnology should acknowledge that the criteria for something counting as knowledge may differ among stakeholders and across time for the same stakeholders. Thus the struggle in discussing nanotechnology does not pit enlightened researchers against an ignorant public, but instead calls forth multiple, potentially competing or converging criteria for knowledge. This tension between different perceptions of knowledge plays a crucial role in conceptions of nanotechnology risks and benefits.

A Gooey Predicament

A scant few paragraphs in *Engines of Creation* refer to how nanoscale self-replicating machines could assemble matter at the molecular level far more rapidly than natural reproductive processes can. This point recalls the familiar experience of automated assembly lines, with machines performing tasks more rapidly and more efficiently than their human counterparts. Citing the population explosion attendant to exponential growth, Drexler notes that the geometric rate of mechanical reproduction could quickly generate synthesized matter that, through sheer numbers, could out-compete natural matter and thereby extinguish life on the planet. Drexler (1986) immediately places nanoassemblers in a zero-sum competition with biological reproduction, observing that the mechanically synthesized devices could "beat the most advanced modern organisms" in the struggle for existence. Rapidly reproducing engineered plants would "out-compete" natural foliage.

> Tough, omnivorous "bacteria" could out-compete real bacteria: they could spread like blowing pollen, replicate swiftly, and reduce the biosphere to dust in a matter of days. Dangerous replicators could easily be too tough, small, and rapidly spreading to stop — at least if we made no preparation. (Drexler, 1986)

The geometric rates of reproduction shorten the time frame of disaster to only "a matter of days." Such an immediate threat, even if highly improbably, renders it worthy of attention. Gray goo stuck in public consciousness. The inability to put brakes on mechanical reproduction re-emerges periodically as a potential brake on enthusiasm about nanotechnology.

Goo oozes into public discussion

The popularity of *Engines of Creation* generated two major effects for the course of nanotechnology. First, it focused attention on mechanosynthesis and nanoassemblers. The spotlight shone on an area of nanotechnology that remains one of the more technically difficult and long-term applications (Atkinson, 2003). If nanoassemblers became a synecdoche for nanotechnology as a whole, then the field would appear as futuristic, speculative, and high risk. Not surprisingly, much subsequent research and discussion of nanotechnology has been devoted to refocusing attention on other, more imminently practical, aspects of nanotechnology, such as "nano pants" that resist stains. Such applications operate within the familiar household realm and appear as enhancements of existing products — incremental changes that add convenience and improve product performance.

Attempting to refute the nasty nanobot scenarios places the respondent in a quandary. Focusing on the technical infeasibility of autoreplication makes nanotechnology more immediately relevant and approachable. If nanoparticles already infuse many common products, then nanotechnology has a presence in daily life. This presence, however, also risks amplifying perceptions of risk. Even highly improbable scenarios become threatening if they apply not to some futuristic intelligent machine but to the automotive wax, suntan lotion, and stain-resistant clothing that we handle, ingest, or inhale daily. Increased frequency of exposure increases likelihood of risk.

A second ripple effect of Drexler's early work was its position at the intersection of scientific knowledge and speculation. Popular writing about technical scientific issues always must straddle the narrow border between methodological precision and comprehensibility. Nanoparticulate goo easily oozed into characterizations of traditional villains of science fiction: nameless, faceless entities antithetical to individualized, unique humans. The 1956 film *Invasion of the Body Snatchers* relied on fears of deindividuation, with the threat of pods that replicated humans while effacing their emotions — in effect, automating the victims. The popular *Terminator* films portrayed a dystopia where machines turned against their human creators in an ongoing struggle for world domination. While not tied to nanotechnology directly, the themes of such films illustrate deep-seated misgivings about self-generating machines and their relationship to humanity.

In late 2003, the goo scenarios received wide dissemination in the *New York Times Magazine* (Osborne, 2003). A brief column by Lawrence Osborne invoked the authority of three sources: a report by the Action Group on Erosion, Technology and Concentration (ETC); Prince Charles; and Drexler. These sources lent credence in various ways to nanobot domination. According the column, Prince Charles became "distressed" after reading an ETC report on gray goo (Osborne, 2003,

p. 73). The only disclaimer in the entire article is a single sentence referring to the director of the ETC saying that "the threat of gray goo lies far in the distant future" (Osborne, 2003, p. 74). Nowhere do any questions arise about the likelihood of the scenario; its occurrence is not a question of whether or under what circumstances but when nanobots will annihilate the earth. Immediately after this less than reassuring caveat, the column raised another specter from the ETC report:

> an equally worrisome but more immediate danger: the green-goo problem. Green goo is roughly the same as gray goo, only it involves the re-engineering of living things to do our bidding. Such cyborg organisms would eat and reproduce as nature intended, but they would be technologically enhanced—with unforeseeable consequences. (Osborne, 2003, p. 74)

The *New York Times Magazine* article resurrected the threat of chaos from humans losing control over their creations. The tension between natural and synthetic creation, or procreation versus manufacture, also casts suspicion on nanotechnology as a transgression against the laws of nature. In this portrayal, nanotechnology seems to usurp sacrosanct reproductive capabilities reserved for "nature" (a term never defined).

The *New York Times Magazine* depiction of knowledge about nanotechnology used several warrants to justify its claims. The plausibility of goo scenarios relies on three sources: ETC, Prince Charles, and Drexler. ETC is characterized as a consumer ally, described as "a Canadian watchdog organization for socially responsible technology" (Osborne, 2003, p. 74). Without any further explanation of the group's credentials (which are, by the way, quite substantial), readers must take the claims at face value, since the source's credibility lies in its affinity with consumer interests; essentially, "Trust these claims, since I'm on your side." The reference to Prince Charles qualifies as an appeal to celebrity, with name recognition serving as a warrant for sharing his "distress." Invoking Prince Charles adds no compelling evidence to support the plausibility of the goo argument. It does, however, demonstrate that the issue should concern people outside the community of scientists. Prince Charles authorizes treating nanoassemblers as not merely a scientific matter but also as a social concern. His involvement justifies non-scientists taking an interest in knowledge that was generated within the scientific community. Drexler, described only as "a former researcher at M.I.T." (Osborne, 2003, p. 73), adds the persona of the prescient scientific researcher whose predictions will come true. Like Drexler (whom the article quotes directly from *Engines of Creation*), the entire article uses the future indicative, thereby magnifying perceptions of risk by rendering conditional events inevitable.

In language invoking a Biblical plague of locusts more than scientific innovation, readers of the *New York Times Magazine* encounter "the gray-goo problem, in which a swarm of millions of rapidly self-replicating microscopic robots, in a ravenous quest for fuel, would consume the entire biosphere until nothing remained but an immense, sludgelike robotic mass" (Osborne, 2003, p. 73). The standard remedy for popularization such as those found here has been to observe the logical fallacies and scientific misconceptions, thereby discrediting the article. This strategy, however, simply preserves the presumed superiority of scientific researchers and derides the public for its naïveté. Non-scientific modes of thinking cannot be simply legislated away at the behest of scientists. Different modes of risk evaluation arise in different forums and among various stakeholders, so it becomes necessary to adapt to these various modes of evaluative modes. "Constructions of risk cannot be easily contained within specific technological fields" (Peterson et al., 2007, p. 121), so perceptions of nanotechnology can be affected by perceptions of other, more familiar and potentially more hazardous, technologies. The spillover of risk perceptions from one realm to another means that the understanding of nanotechnology cannot be isolated from embedded or acquired knowledge about other developments. These technological developments can provide a heuristic for understanding nanotechnology by furnishing precedents that can guide reactions to emerging innovations. For example, one might transfer fears of consuming genetically modified foods to fears of other human-engineered food alterations, such as nanoengineered flavoring agents. The rationale employs a standard argument from analogy, a logical choice because analogical argument renders unfamiliar concepts and situations understandable by comparing them to something more familiar (Schwartzman, 2007).

In late 2003, the Center for Responsible Nanotechnology (CRN) issued a briefing document that attempted to calm fears about gray goo. The document begins by attempting to discredit the concern as "more of a public issue than a scientific problem" and "based on outdated information" (Center for Responsible Nanotechnology [CRN], 2003). Unfortunately the CRN document misses the point. Scientific problems are public issues, especially when science interfaces with everyday life as technology that could have toxicity risks. Scientists must work in tandem with non-scientists to consider the social implications of nanotechnology. "As scientists and engineers work to establish the objective facts about the risks and benefits of nanotechnology, we believe it is also vital that social scientists contribute rigorous research on how the public perceives risks and benefits" (Currall, King, Lane, Madera, & Turner, 2006, p. 153). These public perceptions can affect future funding and acceptance of technology innovations, so it is at best naïve to bifurcate the scientific and social dimensions of nanotechnology.

CRN also attempts to assuage fears of gray goo by reinforcing the authority of the technicians to protect the public. Since the original alarm about gray goo, "Drexler and others have developed models for making safer and more efficient machine-like systems that resemble an assembly line in a factory more than anything biological" (CRN, 2003). Instead of invoking open dialogue about public perceptions of risk, the briefing document leaves the decision making to the scientific researchers who should be entrusted to work on the public's behalf. The realm of knowledge about risk calculations and risk management remains confined to scientists and engineers. Some researchers dealing with nanotechnology-based food products recommend moving in the opposite direction.

> Furthermore, respecting the mix of potential harms and benefits of nanotechnology, regulatory consideration for acquiring public acceptance of the technology ought to appraise not only the accuracy of public risk perceptions, but also the legitimacy of societal and ethical concerns. A greater sensitivity (i.e. understanding and responsiveness) on the part of industry, science, and regulation to the public domain is necessary. (Chau, Wu, & Yen, 2007, pp. 277-278).

Negative public perceptions might be addressed through more vigorous public engagement, i.e., treating knowledge management more as an inclusive than as a sequestering process.

Aside from knowledge management appearing as restricted access, the CRN document takes a puzzling approach to the portrayal of nanoassemblers. Although biological threats might induce fear, "machine-like systems that resemble an assembly line" buy directly into troubling images of depersonalized replication under mechanical rather than human control. In his dialogue *The Abacus and the Rose*, Jacob Bronowski launched the standard attack against mechanistic thinking via the persona of Dr. Amos Harping, a literary critic.

> I would like human beings to stop worshiping the machine. Do you know what all this talk about a scientific culture does to the arts? It makes an architect famous because he says that a house should be a machine for living. I do not want to give my mind to living; I want to give it to life. And I do not want a house to be a machine; I want it to be a home. (Bronowski, 1965, p. 109)

Harping harps on more than the evils of technologically engineered depersonalization. He attacks the central metaphor Western science uses to discuss life. By expressing his dissatisfaction with the mechanistic metaphor, Bronowski's character laments the scientific dehumanization of life, an attitude perpetuated by cross-applying the language of machines to the human world.

The rhetorical allure of goo gobbling the universe makes it a persistent image that outlives its repudiation by scientists. In September 2004, an article in *USA Today* ominously titled "Creating a Monster?" treats gray goo as a specter of Frankenstein that "seems to be lumbering after proponents of nanotechnology" ("Creating a monster," 2004, p. 6D). Despite a complaint from Drexler, whom the article quotes as saying that the gray goo threat has "hampered rational public debate about nanotechnology" ("Creating a monster," 2004, p. 6D), the article keeps the gray goo monster alive. With the subtitle "Nanoparticles hold promise, but there's a gooey downside," gray goo assumes an equal footing alongside the technological advances. By phrasing the gray goo scenario as factual (there "is" a gooey downside, but nanotechnology benefits only "hold promise"), the prospect of goo seems more imminent than the economic and social bonanzas that lie somewhere over the horizon.

The allure of goo and doomsday scenarios

What gives goo its staying power in popular consciousness? Subtitling his 1986 book with the finalistic phrase *Challenges and Choices of the Last Technological Revolution*, Drexler paints a picture of almost limitless technological possibilities. Throughout the book, Drexler predominantly uses the future indicative instead of the future conditional to describe the pending nanotechnology revolution. Nanotechnology *will*, not *could* or *might* under the proper conditions, accomplish dramatic alterations in human life. (Interestingly, the conditional does appear when discussing nanotechnology risks.) Of course a popularization of technical scientific research cannot be expected to include all the ramifications and subtleties of an article in a scholarly journal. Nevertheless, the combination of the future indicative with the definitive finality of the subtitle accomplishes two tasks that help make nanotechnology as attractive as its pseudoscientific rivals. First, these tactics forestall questions about technological feasibility by remaining silent about them. Second, the type and direction of technological innovations assume an air of inevitability. If we *will* undergo such a change, then scientists have determined the course of the future already. Drexler does devote much discussion to the implications and control of new technologies. His primary suggestions for control, design limitations of nanomachines and fact forums (analogous to science courts), still place primary moral responsibility in the hands of technicians themselves (Drexler, 1986).

Drexler apparently noticed his own tendency toward verbal determinism. Chagrined at the popular uptake and scientific repudiation of self-replicating nanoassemblers, he included an explanation of verb tense usage in his next book, *Nanosystems* (Drexler, 1992, p. xix). Drexler clarified his distinction between predictions (signified by the future tense) and conditional predictions (signified by the future conditional tense). But these brief caveats proved to be too little, too late. Even in 2004, Drexler remained busy backpedaling from the gray goo and reassuring readers that self-assemblers posed no threat. The method of reassurance, however, does little to calm fears. Without offering a detailed explanation, the refutation of nanobot doomsday scenarios takes the form of unqualified reassurance: "It has since become clear that all risk of accidental runaway replication can be avoided, since efficient manufacturing systems can be designed, built, and used without ever making a device with the complex additional capabilities that a hypothetical 'grey goo robot' would require" (Phoenix & Drexler, 2004, p. 871). The problem with such a retraction is its inconsistency with so many examples of faulty reassurances from technical experts regarding other technologies. Malignant self-replicating nanobots too easily fit within existing cultural fears and narrative frameworks. Nanotechnology now regularly figures as a recurrent dark force of science fiction. Michael Crichton's novel *Prey* (2002) focuses on a cloud of nanoparticles that escape a laboratory and hunt humans. The recklessly reproducing Replicators of the television series *Stargate SG-1* threaten to overtake the entire universe. Science fiction seems to trump sound scientific knowledge, illustrating our next proposition regarding knowledge management.

The nanobot horror stories function more as what literary theorist Kenneth Burke would call "representative anecdotes" (1969, p. 59) rather than risk scenarios with threats measurable by conventional means: multiplying the event's probability by its anticipated impact. The scientist's or insurance underwriter's concept of risk examines the relationship between likelihood of occurrence and degree of harm. A representative anecdote, however, illustrates that the underwriter's calculus is only one among many choices of how to frame risk. Although perhaps statistically unlikely and thereby owing an infinitesimally small risk by probabilistic standards, representative anecdotes carry weight because of their direct relevance to stakeholders. A vivid story can resonate with audiences regardless of its correspondence to actual events. The open question is whether the defining representative anecdotes about nanotechnology will be dramatic success stories or tales of disaster.

At least three criteria operate in narrative rationality that may not appear to the same degree (or at all) in technical scientific discourse. Far from attenuating scientific knowledge by attending to these issues, considering them might enhance communication about nanotechnology. Speaking across audiences to "creative, curious people in fields close and far" (Sargent, 2006, p. 202) will move toward knowledge management as a collaborative endeavor rather than a struggle to restrict access to knowledge for the sake of protecting power. Communication theorist Walter Fisher would agree. Arguing that narratives can democratize access to knowledge, Fisher (1987) identifies two primary characteristics that compelling narratives exhibit: coherence and fidelity.

Narrative coherence describes the ability of a story to "hang together" with a plausible plot line, believable characters, and internal consistency. Narrative fidelity refers to how a story "rings true" with an audience by calling forth fundamental values of the audience's community. An additional component that Fisher does not identify separately is the narrative's perceived immediacy, or relevance to an audience's priorities. Developments in nanotechnology automatically rank high on immediacy as long as they are presented as solutions to pressing economic and social problems, such as cheap energy production and medical diagnosis. These narrative criteria of coherence, fidelity, and immediacy may complement or conflict with scientific criteria for certifying a claim as knowledge.

The probability that knowledge claims will be propagated depends on their ability to meld with recurrent narratives and not simply on the strength of their evidence. Nanoassembler horror scenarios blended seamlessly with several narrative strands that already enjoyed wide circulation and longevity.

1. Fear of uninhibited reproduction. The sheer numbers of nanobots conjure horrors of swarms descending on outnumbered and therefore doomed humanity. Uncontrolled reproduction resonates narratively in two ways. First, basic assumptions of supply-related value come into play. Burgeoning numbers reduce the value of each individual and lessen the probability of controlling the whole. Thus a gang poses more threat than a small group, a crowd rises challenges for "crowd control," and a mass of almost any animal (such as a pack of dogs) raises more intense alarm than one stray. The threat of massification has some factual basis. The well-documented risky shift phenomenon notes that individuals may adopt more extreme behaviors and make more radical decisions within a group compared to acting alone (Hoyt & Stoner, 1968; Moscovici & Zavalloni, 1969).

A second factor fueling fears of uninhibited reproduction is the analogy with unrestrained sexual promiscuity. To make nanotechnology more understandable, many discussions frame the issues in biological terms (Port, 2000). To envision matter at such minute scales, analogies to the behavior of biological organisms can enhance understanding. These biological terms carry a price. Using biological analogies risks their reification, wherein audiences take the metaphoric comparisons literally. This literalization seems to be exactly what happened with nanoassemblers. Uncontrolled reproduction carries ethical concerns as well. Whereas humans have the power to control their primal urges, any organism that lacks this restraint thereby qualifies as a "lower" form of life.

2. Oppositions between natural and unnatural reproduction. Suspicion of unnatural reproduction, especially the autosynthesis that generates geometric growth rates, places nanotechnology alongside all the suspicious reproductive technologies that have caused widespread trepidation. Restrictions and bans on human cloning demonstrate the prevailing cautions that surround technologically assisted reproduction. Once reproduction edges toward manufacturing organisms instead of creating individual lives, objections will arise that technology has infringed on the sanctity of life.

3. Fears of automation. Concern about automation need not be restricted to neo-Luddites who dread that machines will displace humans. More fundamentally, the rise of nanobots fits into ongoing trend of human crafting, the worker acting as artist, vanishing in the face of cheaper and more efficient mechanical production. This distinction between the unique human product and mass-produced commodities defined the difference between art and reproduction for social critic Walter Benjamin (1969). More deeply, automation threatens the sanctity of anthropocentrism. The approach of posthumanism raises the possibility that humanity has fallen from its privileged place as ruler of the world (a position it has been ensconced in since ordination by God in Genesis). Still worse, humanity might simply be on the way to becoming superfluous if critically important tasks can be delegated to nanomachines that, unlike humans, can replace lost members indefinitely.

4. Human hubris. One explicit moral of the Frankenstein tale was its warning about excessive pride. The lesson of human humility supposedly taught by the Tower of Babel episode never seems to sink in. Overly ambitious scientists, as the ones who most often bump against the limits nature has set, constantly seem to overextend the domain of human knowledge. Nanotechnology provides one of the clearest examples of tempting fate. Since nanotechnology promises breakthroughs in so many sectors, a tragedy easily could be invoked as just punishment for reckless technological progress. The point here is not so much the factual matter of assessing nanotoxicity or the policy matter of developing regulatory guidelines. The key issue at stake is that negative consequences of nanotechnology allow nanotechnology opponents to occupy the moral high ground. Negative effects could generate a "See, we told you so" reaction that inhibits future support for research.

These narrative threads are woven into discussions about the merits of the goo prognostications. Atkinson's (2003) sustained attacks on Drexler's views, which he derisively labels as the doctrines of "Drex and the boys" (p. 257) occur on two fronts. First, Atkinson joins many other researchers, such as the late Nobel laureate Richard Smalley, by arguing the technical infeasibility of malignantly intelligent nanoassemblers. Additionally, Atkinson expresses moral outrage at the hubris exhibited by developing autoreplicators that could become intelligent, sentient beings (precisely the developmental course of the nanoparticles in Michael Crichton's *Prey*). Responding to the destructive nanobot scenarios, Atkinson fumes: "It won't happen. The complexity of this whole scenario is beyond comprehension; it out-natures the very nature that it holds in such contempt" (2003, p. 256). The nanobot horror stories are not only technically infeasible, but morally repugnant. The scenarios culminating in goo of whatever color supposedly hold nature in contempt because they elevate machines to a creative force.

Nanotechnology as a lesson in knowledge management

With some hint of the flavor of nanotechnology discourse now established, the focus now broadens to the implications of discursive practices for knowledge management. Communication about nanotechnology reveals the potential for a shift in understanding the role of science in society. Discussions of nanotechnology reveal a contrast and tension between two paradigms of knowledge management: a more authoritarian role based on the deficit model and a more democratic role based on the dialogic model.

The Deficit Model of Scientific Knowledge

The most commonly prescribed antidote for suspicions about scientific knowledge has been a healthy dose of scientific literacy for the general public (Gardner, 1957). Behind this prescription lies the diagnosis that everyone should be able to compare scientific *explanans* with the natural phenomena being explained, compare theories with nature, and root out the scientific claims that fail to correspond with reality. A similar attitude permeated the general semantics movement whose popularity peaked in the 1940s and 1950s. General semantics proposed that adopting the methods of science promised a remedy for misunderstandings (Chisolm, 1945; Korzybski, 1958). Martin Gardner (1957) classifies general semantics as a "cult" (p. 251) and an imposter to science, although he offers very weak counters to its uses of science.

Despite its noble ambitions, however, the advice to model all rational discourse after science is fundamentally misguided. First, it does not apply to speculative science that deals with predicting phenomena or with developing technologies that cannot be compared to discrete, observable natural phenomena that already exist. Second, scientific literacy alone accomplishes little if theories must be compared with each other and the criteria for judging theoretical adequacy have not been established decisively. Ultimately the scientist's criteria for theoretical adequacy may not match the needs of other audiences, who often crave certainty, lack of ambiguity, and unalterable explanations that assure them a definite place in the universe.

Greater scientific literacy does not address the fundamental human needs that non-scientific (or pseudoscientific) narratives fill despite their failure as scientific theories. Instructions on how to identify crank scientists (Gardner, 1957, pp. 5-10), while helpful, miss the point. The view that the relationship between scientists and non-scientists can be defined primarily in terms of the non-scientific community's absence of scientific knowledge — in effect, ignorance or misunderstanding of science — is known as the deficit model of public understanding of science.

The deficit model suffers from several flaws. First, it bifurcates knowers from non-knowers, in this case scientific researchers from everyone else. This division, aside from its failure to recognize degrees of scientific knowledge, rests on an elitist premise that anyone outside the community of knowledge producers qualifies as ignorant by comparison. As a result, the deficit model endorses a downward model of communication, with the "knowers" somehow expected to enlighten the ignorant masses. Second, the deficit model defines the public as a single undifferentiated mass, failing to recognize the many stakeholders who furnish diverse participants in discussions about nanotechnology. It would be more appropriate to pluralize the participants as "publics" (Pidgeon & Rogers-Hayden, 2007). Third, the deficit model, by defining non-scientists by their absence of knowledge, treats them as "blank slates or empty vessels" (Gregory & Miller, 1998, p. 17). This dismissive attitude actually disempowers the possessors of knowledge as well as the passive public awaiting enlightenment. By ignoring the need to persuade by means of convincing narratives and vivid images, the deficit model offers no rhetorical resources for gaining adherence to scientific innovations. The conception of people as passive receivers of information illustrates a fundamentally naïve and empirically inaccurate view of how human communication operates. As the protests over biotechnologies such as genetically modified organisms demonstrate, non-scientists can provide sites of resistance as well as passive reception. Fourth, the deficit model conflates information with persuasion, not recognizing that when the scientific community or the research sponsor bears responsibility for disseminating research findings, the resultant "factual enlightenment" easily blurs with promotion of a research agenda (Gregory & Miller, 1998).

Despite the drawbacks of the deficit model, more than a vestige of scientific privilege lingers within even carefully prepared orientations to nanotechnology. In a self-guided nanotechnology textbook co-authored by a science writer and the director of the Smalley Institute at Rice University, the authors repeatedly call for open discussions among stakeholders. "Responsible development of nanotechnology also means that the government has to establish public communication channels through the NNI [National Nanotechnology Initiative]…. Open information lines allow the public and the government to make well-informed decisions and build a solid knowledge/trust foundation" (Williams & Adams, 2007, p. 251). Explicitly concerned about "media hype" that could turn nanotechnology into "science fiction" (p. 254), the authors recommend a healthy dose of education. The substance of this education should deal with safety, but it also serves a promotional purpose. "Education is also important in removing potential economic barriers for nanotechnology's use in commerce, industry, healthcare, or environmental cleanup" (Williams & Adams, 2007, p. 255). This point was deemed important enough to merit a question in the end-of-chapter quiz. The implication is that reluctance to invest in nanotechnology stems from ignorance or misconceptions that greater knowledge can remedy. Perhaps, however, increased knowledge could generate greater awareness of risks that would cause investors to proceed with caution. Increased knowledge need not result in more eagerness to embrace nanotechnologies. Indeed, some make dislike the socio-cultural impacts that become more apparent with increase knowledge of nanotechnology.

In 2006, TA Swiss, the Swiss government's Center for Technology Assessment, published a layperson's orientation to nanotechnology. The document, written by a science journalist, was prepared to brief lay participants in moderated public discussions (called "publifocus") about nanotechnology. Although laypeople were the intended audience, the editorial introduction from the publifocus project head retains a hint of the deficit model. The editorial begins by summarizing the enormous promise of nanotechnology, which "is thought to be the key technology for the 21st century." The same paragraph concludes: "Despite all this, the broader public shows little appreciation of nanotechnology's momentous significance" (TA Swiss Center, 2006). Such a statement implies that non-scientists simply lack the needed knowledge to support nanotechnology. This perspective also casts the public information campaign in promotional terms, as an attempt to garner appreciation rather than critical awareness of nanotechnology.

Sometimes the insularity of scientists as knowers appears more subtly. A forum among nanotechnology researchers on *Talk of the Nation*, an interview and call-in program that airs on National Public Radio, reveals the need for more inclusive dialogue, especially beyond scientific specialists. Rosalyn Berne of the Department of Science, Technology, and Society at the University of Virginia, noted that serious dialogues about the social and ethical implications of nanotechnology are just beginning. The pressure to obtain funding, complete research, and publish has narrowed the focus of researchers primarily to the technical issues of getting their work done (Flatow, 2007). John Silcox, a Professor of Engineering at Cornell University, identified a case of "ethical misconduct about labs" as a paradigm case of societal and ethical issues (Flatow, 2007). Larry Goldberg, a scientist with the National Science Foundation, discussed these issues only from the standpoint of following health and safety standards in laboratories (Flatow, 2007). The common thread among all the scientists' observations was their treatment of societal and ethical issues as matters of internal policing indigenous to the community of scientific researchers. Issues of public accountability received no attention, presumably under the assumption that the producers of knowledge should be its proprietors as well. Knowledge management occurs internally, within the scientific community instead of between the scientific community and other constituencies.

With nanotechnology, the application of scientific knowledge often requires introducing new kinds of particles into the environment and directly exposing humans to these particles whose unique properties are only beginning to surface. For example, an editorial commentary in the *Lancet* this year complained about the British government's failure to develop safety standards for nanoparticles, especially in light of how little is known about nanotechnology's health and environmental effects ("The risks of nanotechnology," 2007). The transformation of scientific knowledge into technology, i.e., usable products, extends concern about these innovations far beyond the original researchers. The deficit model of nanotechnology knowledge invokes users of the technology only in a reactive manner, after the discoveries have been made and then introduced into practical applications. If non-scientists engage in nanotechnology discussions only on a "need to know basis," concern arises about who determines the constituencies that need to know and who determines what qualifies as knowledge to share.

From Deficit to Dialogue

The tide has begun to turn against the deficit model of public engagement in nanotechnology. A watershed for reconsidering the techniques of nanotechnology knowledge management occurred with the publication of a report on the state of nanotechnology by Royal Society and the Royal Academy of Engineering in 2004. This report raised caution about overclaiming the potential benefits of nanotechnology, pointing to "hype ('misguided promises that nanotechnology can fix everything') as the factor most likely to result in a backlash against it" (Royal Society, 2004, p. 1). Most important, the report recognized that nanotechnology risks were not understood uniformly by different publics and that nanotechnology needed to be discussed using frameworks defined in terms of different constituencies — not just according to the terms of the scientific researchers. The Royal Society document reflects an understanding of the various ways that constituencies can construct understandings of risk: "the balance of perceived benefits between individuals, private and the public sectors; analogies drawn with other (both stigmatised or accepted) technologies; patterns of media coverage; position of campaigning groups; the existence of significant scientific dispute; and attribution of blame for prominent 'accidents' were these to occur," just to name a few (Royal Society, 2004, p. 64). None of these constructions are dismissed or ridiculed, but instead they receive acknowledgment as factors that can affect the willingness to support nanotechnology.

The shortcomings of the deficit model call for refocusing attention from the producers of knowledge as the controllers of communication flow and style and toward the ways that various constituencies construct knowledge and evaluate knowledge claims. The traditional deficit model reinforces a linear flow of communication that reflects a definite sequence and hierarchy between knowledge producers and consumers, a relationship illustrated in Figure 1. The figure demonstrates a "trickle down" vision of knowledge management, wherein the supply of knowledge is regulated by the producers (the scientific researchers).

Increasingly, discussions of nanotechnology have stressed the centrality of broad public engagement as early as possible. Early, inclusive participation in evaluating the impact of nanotechnology can take public dis-

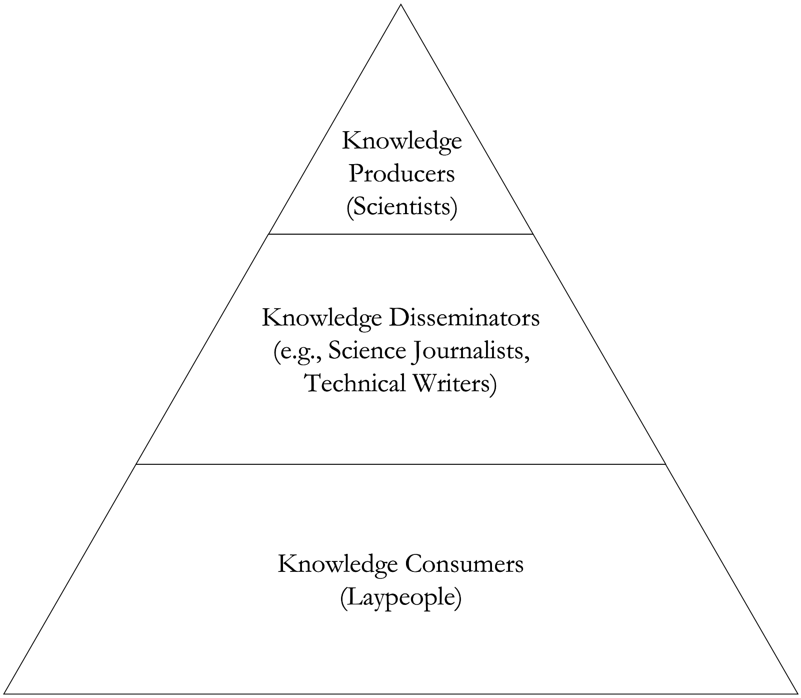

Figure 1. Linear, hierarchical conception of knowledge flow

course beyond the extremes of hype and horror. This proactive approach would enhance preparation for societal and ethical implications before opinions become stultified by premature fears or euphoric speculations (Sargent, 2006). The opportunity for broad engagement arises especially in the current "upstream" stage of nanotechnology (Pidgeon & Rogers-Hayden, 2007), a point when public opinions about nanotechnology have not solidified and representative anecdotes have not yet become entrenched.

It remains challenging to reconceptualize management of scientific knowledge because of limitations inherent in the terminology. The problems with "management" carrying connotations of restrictive access to knowledge and maintenance of power were covered earlier in this chapter. The term "non-scientists" also conjures the deficit model of scientific knowledge by identifying members of constituencies besides scientists only by a negative trait: their position outside a scientific community. This terminology could benefit from the same constructive moves made in critical race theory to re-classify "non-Whites" on the basis of their positive qualities rather than on their "absence" of the presumed default skin color or culture. Finally, bifurcating "science" and "public" inaccurately conceives of each constituency as a unitary group, when a range of opinions, perspectives, and value systems infuse discussions of nanotechnology's hopes and hazards.

A more productive way of visualizing knowledge management would be to treat each constituency involved with nanotechnology as, at least in some senses, a learning community. As a learning community, each constituency would be open to influencing and being influenced by other constituencies. Rather than engaging each other as antagonists, a relationship fostered by the deficit model, constituencies could approach nanotechnology in a collaborative mode. This collaborative mode is fostered by grounding discussions in a philosophy of dialogue. Peter Senge (1990) articulates the basic mindset of dialogue that facilitates discussion and learning from multiple constituencies: "The discipline of team learning starts with 'dialogue', the capacity of members of a team to suspend assumptions and enter into a genuine 'thinking together"' (p. 3). The knowledge management literature typically follows Senge in discussing dialogue as an intra-group phenomenon that builds organizational cohesiveness and adaptability. The considerations of this chapter suggest that dialogue can lower the boundaries that separate various stakeholders and compartmentalize knowledge in ways that protect hierarchies of power.

The notion of dialogue configures constituencies as learning communities in the sense that they become open to knowledge that can be generated by any other constituency, not only the knowledge that arises from within their own community. Figure 2 illustrates how various constituencies might be activated by their concern for a specific issue, such as discovery of a particular nanotechnology innovation or toxicity of a type of nanoparticle. The constituencies can multiply or attenuate depending on whether they see the issue as salient. A dialogically informed approach to nanotechnology knowledge management emphasizes that the paths of persuasive influence can flow among any of the constituencies, all of which remain permeable to influence. The flow of information bears minimal resemblance to the top-down dissemination or centralized dissemination. Although more chaotic, the information flow in the dialogic approach yields a significant advantage: proactive

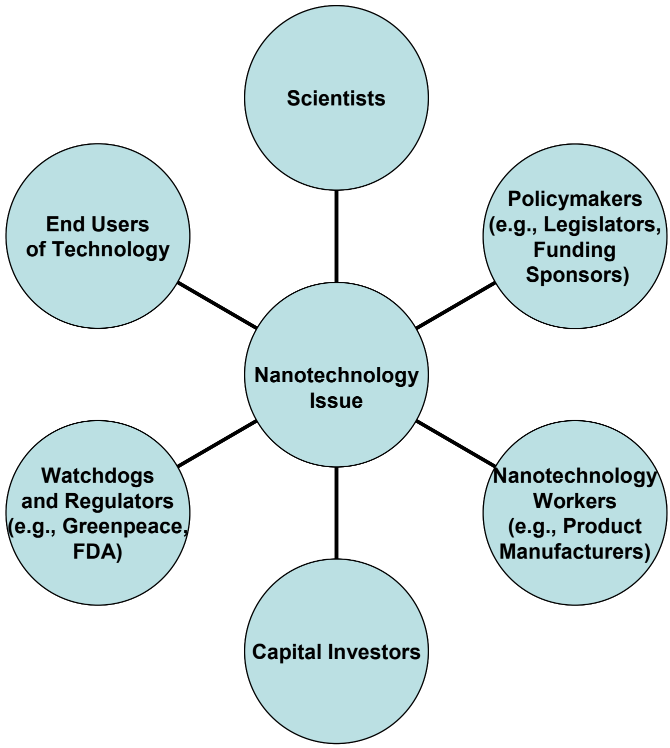

Figure 2. Convergence of constituencies in knowledge sharing

consideration of multiple constituencies as participants in decision making.

The dialogical approach presented here represents more a philosophical orientation or guiding principle than a specific discursive method. Several formats for public dialogues about nanotechnology have been offered, such as the long list of forum options developed by the Royal Society (2004) and the publifocus groups assembled by TA Swiss (2006). The exact method of dialogic engagement provides fodder for future research. The dialogic attitude provides the core concept for making discussions of nanotechnology models of proactive public engagement, with multiple stakeholders willing to ask and answer challenging questions, learn from various stakeholders, and exhibit mutual adaptability. For example, psychometric research has found that lay audiences prioritize food and health applications of nanotechnology as areas of greatest potential risk (Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007). Knowing these priorities should enable other constituencies not simply to play on these fears as promising sites for constructing doomsday scenarios, but to intensify frank and open discussions of risk management in these domains. The mentality of dialogue encourages constituencies to view each other as potential sources of knowledge rather than solely as audiences whose compliance must be gained.

Treating communities of stakeholders as learning organizations enhances understanding of nanotechnology and science generally in a public forum. Several important implications follow from shifting toward this dialogical outlook. First, a dialogical perspective levels the presumptive hierarchies of knowledge that can restrict communication and entrench power. Second, the view of knowledge management advocated in this chapter introduces a multi-directional creation, flow, and testing of knowledge among stakeholders, requiring mutual adaptation instead of a top-down model of knowledge dissemination and compliance gaining. Third, arising from the multi-directional path of knowledge, a more democratic approach to knowledge management provides opportunities for negotiating knowledge claims rather than imposing them. Finally, a collaborative approach to knowledge management offers opportunities for collective considerations of risks and benefits instead of investing one constituency with the exclusive responsibility to "fix" things or "make the best of" technologies that affect their lives.

Chapter Summary

This chapter has focused attention on the linguistic and political consequences of knowledge management. Specifically, because of the dominant choices made about knowledge management, namely that knowledge is an economically vital commodity and that it can be brought under managerial control, knowledge management can readily acquire a conservative cast that maintains a set of socially accepted myths and practices (Alvesson, 1993) that limit the democratic constitution and consideration of knowledge. In other words, knowledge management should be construed as a site of struggle or collaboration. "Seeing knowledge as a simple resource in the hands of capable subjects may...bring...understanding to a premature closure: knowledge — based upon, or fused with, myths, fashions and power-potentials — may control subjects and institutions as much as the opposite" (Alvesson & Kärreman, 2001, p. 1000). To avoid this closure, knowledge may be seen as collaborative, constituted, and controversial, and management may be seen as a coordinating activity, rather than a controlling one (Deetz, 1992, 1995).

Two specific examples demonstrate how discourse abut nanotechnology operates in public discussions. The playful rendition of C_{60} as buckyballs potentially insulates scientists from suspicions of malignancy, but it also might unrealistically lower perceptions of nanoparticle risks. The pessimistic goo scenarios demonstrate how narratives about nanotechnology can persist independently of scientifically authorized knowledge.

Frameworks such as the deficit model compartmentalize knowledge, protecting positions of scientific power and dividing the scientific community from other communities that can affect how technologies enter into daily life and achieve acceptance. Since knowledge is ideologically laden, its management has sociopolitical implications about who should be empowered to know. Scientists have occupied a privileged position in the knowledge hierarchy, but they form only one of several intersecting constituencies. A dialogically informed view of nanotechnology knowledge management recognizes that different constituencies exercise checks and balances on each other. These mutually informing and perhaps challenging relationships are better described as interwoven epistemologies than as a hierarchy of constituencies with the supposedly ignorant public remediated by those designated as the "keepers" of knowledge.

Discussion Questions

1. How does nanotechnology provide an opportunity to move from an authoritarian, restrictive view of knowledge management to a more democratic, inclusive approach?

2. Examine some articles about nanotechnology that have appeared recently in popular publications or web sites. How do they exemplify tendencies toward hype or fear mongering about nanotechnology? What sources of information might provide unbiased and technically accurate knowledge about nanotechnology?

3. What kinds of active influence could non-scientists have over the uses of nanotechnology? What sorts of forums would be

appropriate for scientists and non-scientists to discuss nanotechnology as partners in dialogue?

4. How has nanotechnology figured in science fiction aside from the examples discussed in this chapter? What accounts for the recurrent fascination with nanotechnology as a constructive or destructive force?

5. How do scientific standards for evaluating knowledge claims differ from standards that might be used by people who use nano-engineered products? More broadly, what should a scientific researcher do to convince you of the safety of nanotechnology? Would discussion of the probability of harms provide sufficient reassurance? Why or why not?

6. What examples of genuine dialogue have you encountered? What factors contributed to the development of dialogue? How did dialogue affect the acquisition, evaluation, and formation of knowledge?

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